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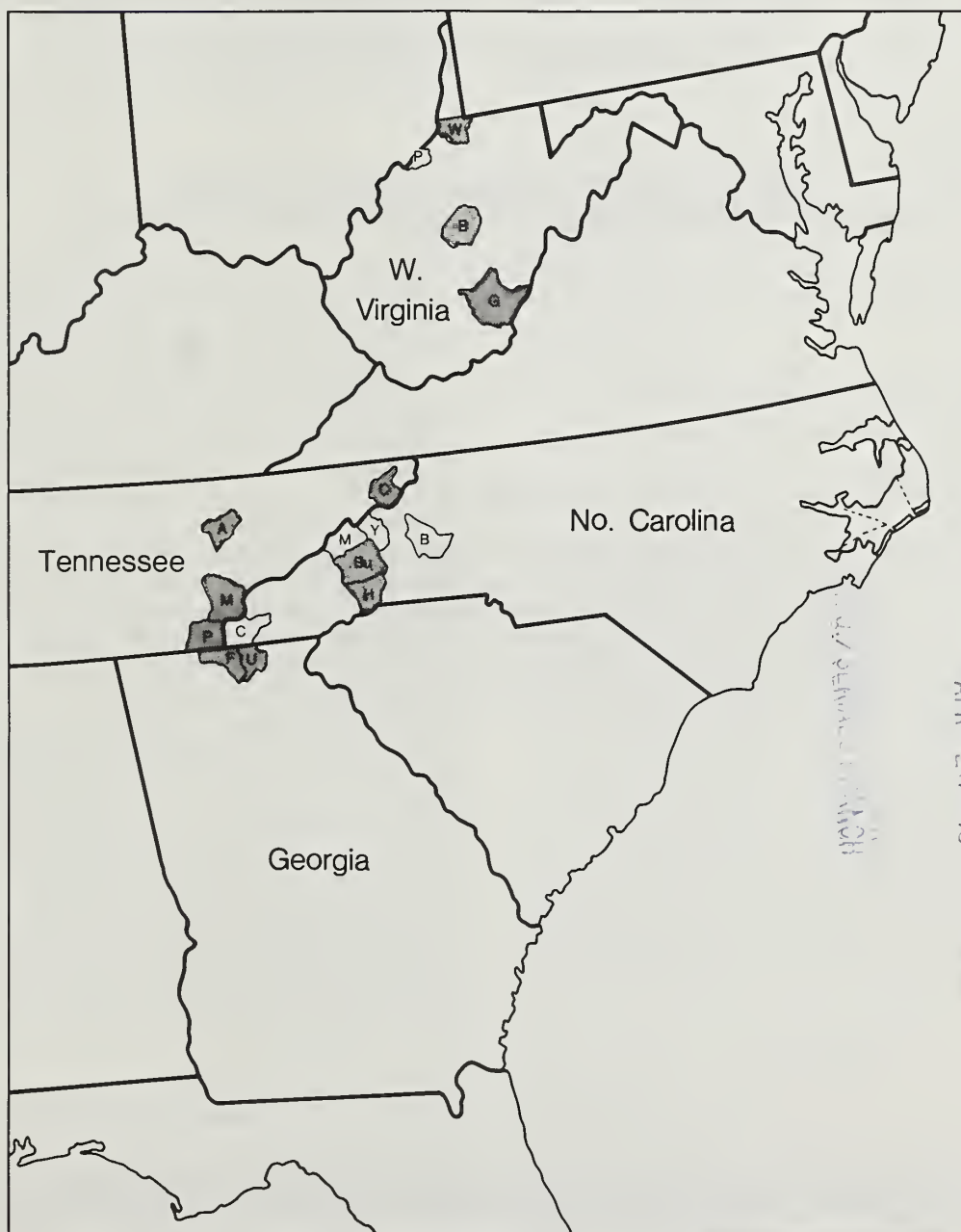
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Genetic Variation in Eastern White Pine: A 15-Year Test of Provenances in Eastern Nebraska

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Genetic Variation in Eastern White Pine: A 15-Year Test of Provenances in Eastern Nebraska

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Abstract

Provenances of eastern white pine from eastern Tennessee, northern Georgia, and western North Carolina produced trees of superior height, diameter, and volume. Height growth was inversely correlated with latitude, but with non-clinal ecotypes. Trees and provenances of superior height are identifiable by age 11. Height differences between original and replacement seedlings persisted throughout a 15-year period.

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David F. Van Haverbeke

Management Implications

Landscape specimens and screen plantings of eastern white pine are often found in many towns and cities throughout the eastern central Great Plains. However, their origins are mostly unknown, making repeat plantings difficult.

Identification of eastern white pine sources that are adapted to the Great Plains environment would reduce planting failures caused primarily by ill-adapted seed sources, and would increase the number of conifer species that can be planted successfully in the eastern central Great Plains.

Introduction

Southern Appalachian sources of eastern white pine (*Pinus strobus* L.) were assembled by the late Jonathan W. Wright of Michigan State University, and became available for testing in Nebraska in the late 1960's through the Cooperative Regional Tree Improvement Project (NC-99) of the North Central States Agricultural Experiment Stations (table 1). Most plant material native to the warm, deep South usually cannot be moved successfully into the colder Upper Midwest. However, the planting site in Nebraska is at 41° N. latitude, and some of the northernmost sources of this eastern white pine material originated from 38° N. to about 40° N. latitude. Most of the remaining sources originated from the mountainous southern Appalachians, where colder temperatures than in lowland southeastern and southern locales occur.

The probability of finding sources of eastern white pine from the southern Appalachian mountain region suitable for shelterbelt planting, Christmas tree culture, and landscaping in Nebraska seemed high enough to warrant testing these provenances. Origins of Douglas-fir (*Pseudotsuga menziesii*) (Read and Sprackling 1976, Van Haverbeke 1987), southwestern white pine (*Pinus strobiformis*) (Van Haverbeke 1983), and Colorado blue spruce (*Picea pungens*) (Van Haverbeke 1984), originating from latitudes as low as 32° N., in the Southwest, have grown vigorously in eastern Nebraska for as many as 20 years.

Materials and Methods

Two-year-old transplant (1 + 1) seedlings of 135 sources of southern Appalachian eastern white pine were machine-planted in the spring of 1969, at the

University of Nebraska Horning State Farm, near Plattsmouth, Neb. (Sprackling and Read 1976) (table 1). Seedlings were planted in seven replications of 2-tree linear plots 7 feet apart, in rows 13 feet apart. Some sources represented half-sib seedlings from single parent trees; others consisted of composite samples from several trees collected at a location. The test design was that of a randomized complete block with seven replications. Failed first-year seedlings were replaced at the beginning of the second season with seedlings transplanted from line-out rows adjacent to the plantation, or as potted seedlings held-over in a shadehouse.

Unlike the 7-year analysis (Sprackling and Read 1976), in which provenances were grouped by geographic location, provenances were retained as separate entities in this analysis. All seed sources, regardless of their composition, were treated similarly, and are referred to as provenances.

Survival was calculated for those provenances that had trees living after 15 years. Survival proportion was calculated as:

$$\frac{\text{Number of trees surviving after 15 years}}{\text{Number of original trees planted}}$$

Because the number of trees originally planted was not known, that number was estimated as the total number of trees surviving to age 15 and the number of replanted trees. Survival proportions were analyzed for significant differences using a procedure for many proportions given by Fleiss (1981).

Height and survival of provenance trees were analyzed first, by analysis of variance, to determine if differences existed among provenances; and secondly, by ISODATA cluster analysis (Ball and Hall 1965), to identify different sets of homogeneous provenances. The latter identifies sets (clusters) of provenances that perform differently but whose performances are similar within sets. The standard multiple comparison procedure within the context of an analysis of variance cannot successfully separate provenances into meaningful groups; and the results are difficult to present and interpret. Age/age correlations were computed to determine at what age provenances of superior height could be identified.

Results

Survival

There were no significant differences in survival among the 135 provenances. However, sensitivity of the test was low because of the small number of trees tested

Table 1.—Eastern white pine provenances tested in eastern Nebraska.

Seedlot origin no. ¹	State and county of seed origin	Trees in collection	Latitude	Longitude	Elevation
		(no.)	(°N.)	(°W.)	(ft.)
571-79	WV Wetzel	9	39°30'	80°45'	800
555,58,61,62,63	WV Pleasants	5	39°20'	81°07'	800
580-84,86,87,89	WV Braxton	8	38°45'	80°30'	1000
453, 590-94	WV Pocahontas	6	38°20'	79°53'	2800
477-78	WV Pocahontas	?	38°08'	80°01'	2600
564-68	WV Greenbrier	5	38°00'	80°14'	2300
461-64,69,79,80	WV Greenbrier	5 +	37°58'	80°08'	2330
427	WV Mercer	?	37°30'	81°00'	2500
476	VA Rockingham	?	38°40'	79°00'	1500
470	VA Botetourt	4	37°31'	79°37'	1550
420	TN Carter	10	36°20'	82°04'	--
532-34,36-41	TN Anderson	9	36°00'	84°10'	900
503-12	TN Monroe	10	35°20'	84°10'	1800
493-502	TN Polk	10	35°00'	84°32'	1500
428-35	NC Yancey	8	35°58'	82°15'	2000
422,83,86-89,552	NC Burke	11 +	35°51'	81°51'	1470
551	NC Madison	?	35°50'	82°40'	2000
410-18,36,37	NC Buncombe	11	35°30'	82°36'	2600
452	NC Graham	1	35°20'	83°52'	2040
438-41,43	NC Henderson	5	35°10'	82°50'	3000
421	NC Macon	5	35°06'	83°12'	4000
522-31	NC Cherokee	10	35°05'	84°10'	1500
546-48	GA Rabun	?	34°52'	83°19'	1800
513-21,42-45	GA Fannin, Union	13 +	34°40'	84°10'	1970

¹The prefix digit 3 was omitted from the Michigan State University accession numbers.

for each provenance. There may be survival differences among provenances, but a larger sample size would be needed to test these differences.

Height, Diameter, and Volume

Plotting of 15-year height and diameter data of original and replanted trees, in this evaluation, indicated a sufficient difference between the two age groups to warrant exclusion of the replanted trees from analysis (fig. 1). Analysis of variance indicated significant differences among provenances for both 15-year heights and diameters ($P=0.005$).

The ISODATA cluster analysis using both height and diameter identified four homogeneous clusters whose mean heights and diameters ranged from 33.3 feet and 7.4 inches in Cluster I to 27.6 feet and 5.4 inches in Cluster IV (table 2). Four times as many provenances (36 vs. 8) occurred in Cluster I as in Cluster IV (table 2, fig. 2). In Cluster II, the margin of difference was still 2.5 times in favor of the Tennessee-North Carolina-Georgia provenances.

Provenances in Cluster I contain trees with 18%, 33%, and 56% more volume (d^2h) than provenance trees in Clusters II, III, and IV, respectively. Provenances asterisked in table 2 for both height and diameter superiority in Cluster I (mostly from Tennessee) yielded 6% more volume than the average of all provenances in Cluster I. These predominantly Tennessee provenances were about equally divided between Anderson (A) and Polk (P) counties in Tennessee (fig. 2).

As expected, height growth and diameter were significantly correlated ($r=0.707$). Height and diameter were inversely and significantly correlated with latitude ($r=-0.208$ and $r=-0.168$), respectively; but these latter correlations, while significant, are not too strong ($P=0.0001$).

Age/Age Correlations

Matrices of age/age correlations (r) were computed for tree height at the tree and provenance levels (table 3). Coefficients computed using individual tree data were slightly lower than those using provenance means for all age comparisons. Provenances of superior height at age 15 can be identified at age 11.

Discussion

Sprackling and Read (1976) reported that survival of these provenances averaged 75% after 7 years in the field, but neither survival nor height growth was correlated with latitude of origin. Trees from a Polk County, Tennessee source were the fastest growing, averaging 10.9 feet; trees from a nearby source were the slowest growing, averaging 8.2 feet. Trees from southern sources, in general, had the longest needles, and northern sources flowered first. Most origins were recommended for ornamentals and Christmas trees, but none were recommended for windbreaks. Progeny height growth was not related to parent tree height growth. The

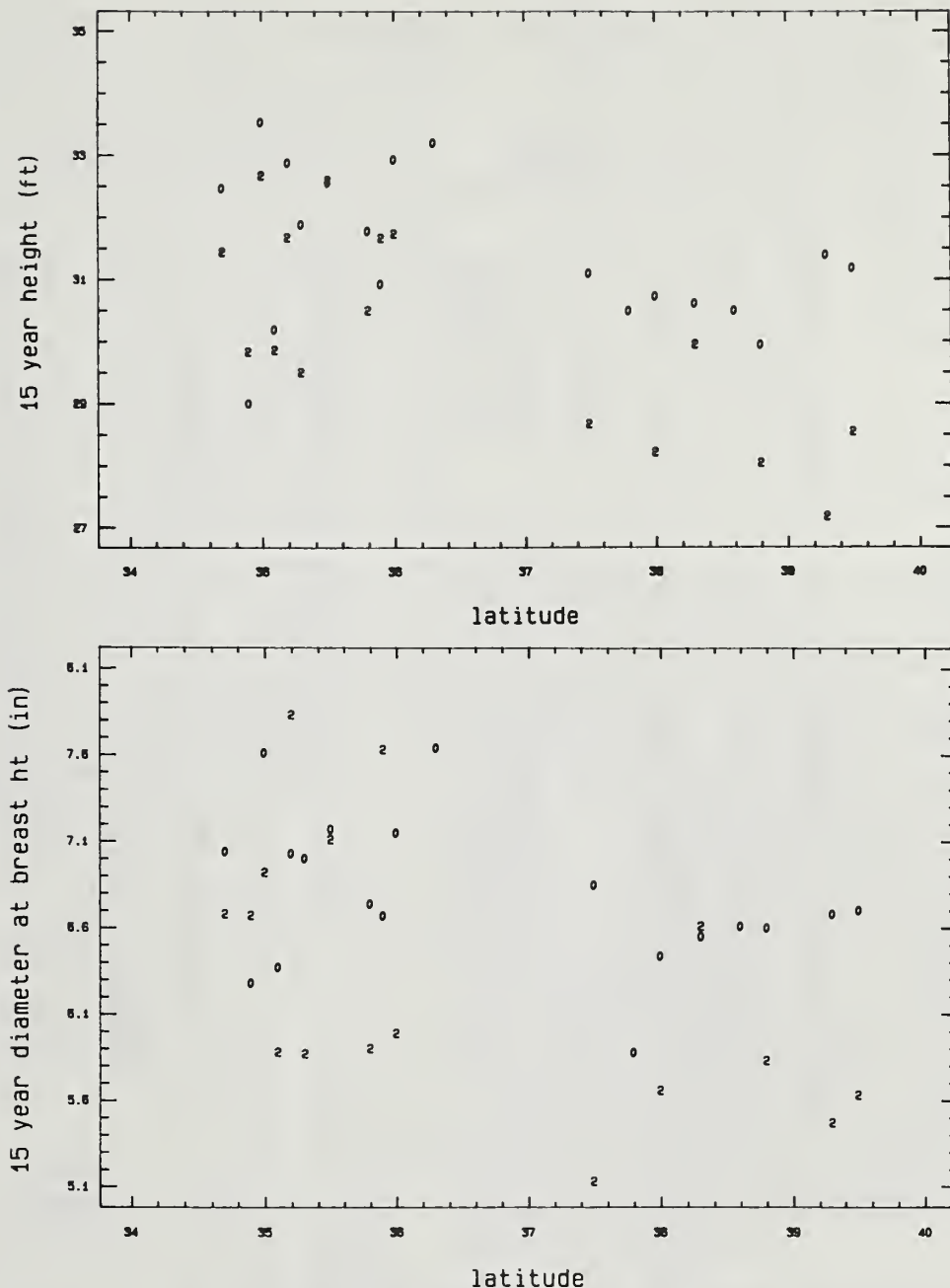


Figure 1.—Comparison of fifteen-year heights and diameters of originally planted (o) and replanted trees (2) in a Nebraska test of eastern white pine provenances. (Data are provenance means ranked by latitude).

ability of eastern white pine, from as far south as the north Georgia mountains, to survive in the much colder climate of Nebraska was speculated to result from residual cold-hardy genes retained in the germ plasm during the confinement of the species in the southern Appalachian mountains during the Pleistocene Ice Age. This phenomenon enabled it to migrate northward into colder climates following retreat of the glaciers.

Exclusion of "replant" trees from this analysis is supported by the conclusion of Kriebel (1979) that size differences between originally planted and replacement seedlings of eastern white pine, of the same seed source, are significant and can persist for as long as 20 years.

Contrary to the results reported by Sprackling and Read (1976) in their 7-year evaluation of this material and others (Wright et al. 1963, Garrett et al. 1973, Funk 1979), height growth in this evaluation was significantly, even if weakly, correlated (inversely) with latitude. Southern Appalachian provenances, especially those from eastern Tennessee, western North Carolina, and northern Georgia, generally outgrew more northerly provenances in this Nebraska test. This is in agreement with the results reported by other researchers (Santamour 1960; Sluder 1963; Funk 1964; Genys 1968, 1987; Sluder and Dorman 1971; Thor 1974; Funk and Jokela 1979; Demeritt and Kettlewood 1976; Williams and Funk 1978;

Table 2.—Ranked ISODATA height/diameter clusters of 135 eastern white pine provenances tested in eastern Nebraska.

Cluster I					Cluster II					Cluster III				
Prov. no.	State	County	Ht.	Dia.	Prov. no.	State	County	Ht.	Dia.	Prov. no.	State	County	Ht.	Dia.
			(ft.)	(in.)				(ft.)	(in.)				(ft.)	(in.)
*540	TN	Anderson	34.5	7.3	537	TN	Anderson	33.7	6.7	440	NC	Henderson	31.8	5.7
*514	GA	Fannin	34.2	7.8	438	NC	Henderson	33.7	6.6	453	WV	Pocahontas	31.2	6.2
*520	"	"	34.2	7.7	436	"	Buncombe	33.1	6.8	590	"	"	30.9	6.4
*437	NC	Buncombe	34.2	7.4	479	WV	Gr. Brier	33.0	6.5	528	NC	Cherokee	30.8	6.6
*494	TN	Polk	34.1	7.8	501	TN	Polk	32.9	7.0	543	GA	Fannin	30.8	6.6
*499	"	"	34.1	7.6	410	NC	Buncombe	32.9	6.9	526	NC	Cherokee	30.8	6.5
*533	"	Anderson	34.1	7.2	572	WV	Wetzel	32.8	6.6	547	GA	Rabun	30.7	6.7
*497	"	Polk	34.0	8.1	517	GA	Fannin	32.7	7.0	433	NC	Yancey	30.7	6.6
*498	"	"	34.0	7.6	518	"	"	32.7	6.7	592	WV	Pocahontas	30.7	6.4
*509	"	Monroe	34.0	7.0	521	"	"	32.6	6.9	576	"	Wetzel	30.7	6.3
*541	"	Anderson	33.9	7.1	542	"	"	32.5	7.2	586	"	Braxton	30.6	6.7
*539	"	"	33.8	7.5	415	NC	Buncombe	32.5	6.8	522	NC	Cherokee	30.6	6.6
*500	"	Polk	33.7	8.2	487	"	Burke	32.3	6.9	565	WV	Gr. Brier	30.6	6.3
502	"	"	33.5	7.3	519	GA	Fannin	32.3	6.8	511	TN	Monroe	30.5	6.6
536	"	Anderson	33.3	7.4	524	NC	Cherokee	32.2	7.0	476	VA	Rockingham	30.5	6.6
534	"	"	33.3	7.2	428	"	Yancey	32.2	7.0	568	WV	Gr. Brier	30.5	6.5
420	"	Carter	33.2	7.6	512	TN	Monroe	32.1	7.0	427	"	Mercer	30.5	5.9
493	"	Polk	33.1	7.7	430	NC	Yancey	32.2	7.0	567	"	Gr. Brier	30.4	6.5
545	GA	Union	33.1	7.4	418	"	Buncombe	32.1	6.2	480	"	"	30.4	6.2
443	NC	Henderson	33.1	7.2	515	GA	Fannin	32.0	6.7	462	"	"	30.2	6.7
416	"	Buncombe	33.0	7.5	555	WV	Pleasants	32.0	6.6	421	NC	Macon	30.2	6.3
496	TN	Polk	33.0	7.3	513	GA	Fannin	31.9	7.0	563	WV	Pleasants	30.1	6.4
532	"	Anderson	32.9	7.2	577	WV	Wetzel	31.9	7.0	478	"	Pocahontas	30.0	6.3
538	"	"	32.9	7.1	558	"	Pleasants	31.9	7.0	422	NC	Burke	29.9	6.5
441	NC	Henderson	32.8	7.6	529	NC	Cherokee	31.9	6.4	546	GA	Rabun	29.8	6.6
507	TN	Monroe	32.8	7.5	432	"	Yancey	31.8	7.1	488	NC	Burke	29.8	6.0
574	WV	Wetzel	32.8	7.2	551	"	Madison	31.8	6.7	463	WV	Gr. Brier	29.7	6.1
413	NC	Buncombe	32.7	7.4	562	WV	Pleasants	31.8	6.6	564	"	"	29.4	6.5
439	"	Henderson	32.7	7.2	566	"	Gr. Brier	31.7	6.9	578	"	Wetzel	29.2	6.1
503	TN	Monroe	32.7	7.2	571	"	Wetzel	31.7	6.7	531	NC	Cherokee	29.1	6.5
411	NC	Buncombe	32.6	7.4	508	TN	Monroe	31.7	6.4	527	"	"	29.0	6.2
506	TN	Anderson	32.5	7.4	435	NC	Yancey	31.6	7.3	510	TN	Monroe	28.8	6.7
414	NC	Buncombe	32.5	7.2	573	WV	Wetzel	31.6	6.9	593	WV	Pocahontas	28.6	6.2
434	"	Yancey	32.3	7.5	417	NC	Buncombe	31.5	7.4	575	"	Wetzel	28.6	6.6
495	TN	Polk	32.2	7.4	580	WV	Braxton	31.5	7.4	N = 34 \bar{x} = 30.19 6.40				
464	WV	Gr. Brier	32.2	7.4	486	NC	Burke	31.5	7.0					
581	WV	Braxton	32.2	7.3	431	"	Yancey	31.5	7.0					
N = 37 \bar{x} = 33.31 7.43					516	GA	Fannin	31.5	6.7					
* Predominantly Tennessee provenances of greater volume					594	WV	Pocahontas	31.4	7.0					
					452	NC	Graham	31.4	7.0					
					579	WV	Wetzel	31.4	6.8					
					582	"	Braxton	31.3	7.0					
					544	GA	Fannin	31.3	7.0					
					483	NC	Burke	31.3	6.6					
					477	WV	Pocahontas	31.2	6.6					
					505	TN	Monroe	31.1	6.9					
					470	VA	Botetourt	31.1	6.8					
					552	NC	Burke	31.1	6.8					
					561	WV	Pleasants	31.1	6.7					
					412	NC	Buncombe	31.0	7.2					
					429	"	Yancey	31.0	7.0					
					504	TN	Monroe	31.0	6.9					
					591	WV	Pocahontas	30.8	7.0					
					489	NC	Burke	30.8	7.0					
					523	"	Cherokee	30.8	6.8					
					583	WV	Braxton	30.6	7.0					

des Bordes and Thor 1979). Additional provenances of high performance, as those in Clusters I and II, might be found along the Tennessee-North Carolina border astride the Appalachian ridge. Of special significance for the Plains region, Funk (1971), Lee (1974), Funk et al. (1974) and Wright et al. (1976, 1979) reported faster height growth in the Central States for trees from southern Appalachian provenances. However, Funk (1971) and Lee (1974) reported that the height advantage of the southern provenances diminished from being 81% taller than other sources at age 6 to being only 39% taller at age 10.

Genys (1968), Thor (1974), and des Bordes and Thor (1979), in addition to reporting the existence of clinal variation in height growth, also pointed to the presence within the cline of non-clinal adapted ecotypes. This phenomenon also was evident in the 7-year results reported by Sprackling and Read (1976), where the fastest growing provenances from Polk County, Tennessee, were only 25 miles west of Cherokee County, North Carolina—origin of the slowest-growing trees. Also, even though inspection of provenance distribution in the cluster assignments in table 2 reveals a predominance of southern Appalachian provenances in Clusters I and II and a preponderance of northern provenances (West Virginia) in Clusters III and IV, there are northern provenances in Clusters I and II and southern provenances in Clusters III and IV (table 2).

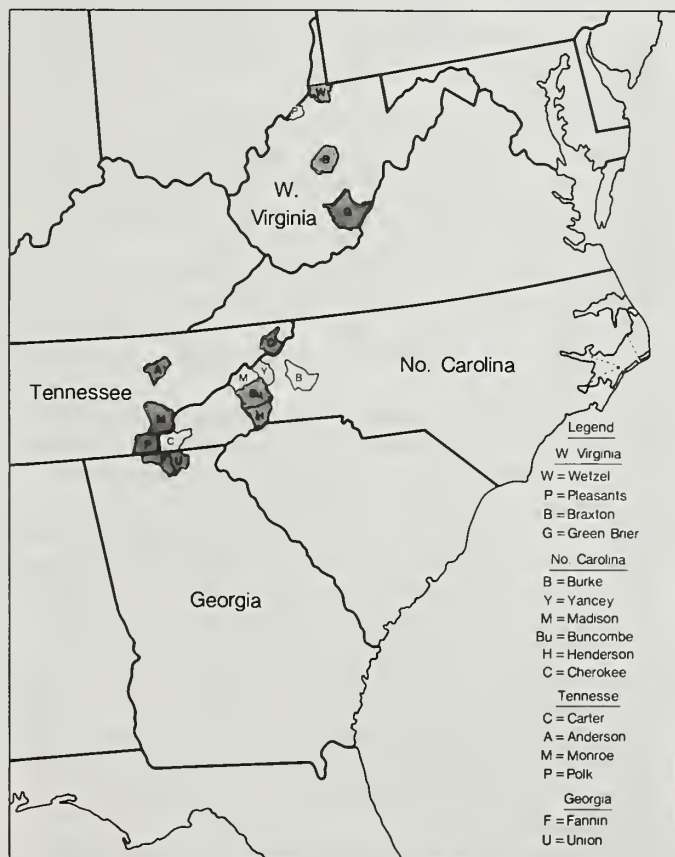


Figure 2.—Counties in which provenances containing trees of tallest height and largest diameter originated [Cluster I (shaded), Cluster II (white)].

Table 3.—Age/age correlations computed using provenance mean (upper value) and individual tree (lower value) data among ages 2 to 15 (field age) for 135 eastern white pine provenances.

		Provenance/tree age correlations				
Age	-----	2	6	7	11	15
Year	-----	1970	1974	1975	1979	1983
2						
1970			.48 ¹	.49	.47	.47
			.47	.46	.39	.33
	6			.97	.86	.73
	1974			.96	.80	.66
		7			.90	.80
		1975			.85	.72
				11		.90
				1979		.85
					15	
					1983	

¹All correlation coefficients are significant at the 0.001 level of probability.

High correlation between tree height and diameter is common (Wright 1970, Demeritt and Kettlewood 1975). Sprackling and Read (1976) suggested the feasibility of growing eastern white pine as a long-term investment for sawtimber in the (eastern) central Great Plains because of its rapid rate of height and diameter growth. Kriebel (1978, 1983) reported volume gains of 50% or more over local genotypes at ages 15 to 20 by using seed from selected southern Appalachian stands. Funk (1979) reported superiority of eastern Tennessee provenances in volume production and that differences in volume increment related to provenance remained consistent from age 5 to ages 16 and 17.

This evaluation indicates that provenances of superior height (and diameter) growth can be identified by age 11. Funk et al. (1974) and Funk and Jokela (1979) reported that height at age 5 was a good predictor of height and diameter at age 20. However, Demeritt and Kettlewood (1975) cautioned that relative differences in height and diameter between northern and southern sources of eastern white pine had diminished between the 10- and 16-year measurements.

Conclusions and Recommendations

Among the provenances tested, those from Anderson (A), Carter (C), Monroe (M), and Polk (P) counties in Tennessee; Fannin (F) and Union (U) counties in Georgia; and Buncombe (Bu), Henderson (H), and Yancey (Y) counties in North Carolina contained trees of superior height and diameter (and volume) growth, and are considered best for planting in eastern Nebraska (fig. 2).

The recommendations proposed in the 7-year evaluation of this material (Sprackling and Read 1976) are, for the most part, still appropriate for the use of eastern white pine in eastern Nebraska:

1. Best performance can be expected in the eastern half of Nebraska (east of the 100th meridian), where rainfall is higher, wind is less, and temperatures are

milder than in western Nebraska and the western Central Plains.

2. Eastern white pine should be planted on sites affording protection from severe wind to prevent winter burn, summer desiccation, and the development of asymmetrical (windblown) crowns.
3. Most provenances tested in the 7-year analysis are still recommended in eastern Nebraska for ornamentals and for Christmas trees.
4. While not considered the most desirable conifer species in terms of crown density and retention of lower branches, and even though it reputedly has a tendency to deteriorate in middle age, the use of eastern white pine, especially in multiple rows, for farm windbreaks and other protective and screen plantings appears to be acceptable.
5. Eastern white pine continues to be one of the fastest growing conifer species under test in eastern Nebraska; and because it has not been subject to attack from white pine blister rust or the white pine weevil, it could be considered for wood production on a limited scale, on selected sites, as a long-term investment.

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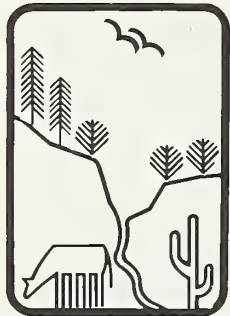
Provenances of eastern white pine from eastern Tennessee, northern Georgia, and western North Carolina produced trees of superior height, diameter, and volume. Height growth was inversely correlated with latitude, but with non-clinal ecotypes. Trees and provenances of superior height are identifiable by age 11. Height differences between original and replacement seedlings persisted throughout 15-year period.

Keywords: eastern white pine, *Pinus strobus*, provenance, age/age correlations, effect of seedling replacement on growth





Rocky
Mountains



Southwest



Great
Plains

U.S. Department of Agriculture
Forest Service

Rocky Mountain Forest and Range Experiment Station

The Rocky Mountain Station is one of eight regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

RESEARCH FOCUS

Research programs at the Rocky Mountain Station are coordinated with area universities and with other institutions. Many studies are conducted on a cooperative basis to accelerate solutions to problems involving range, water, wildlife and fish habitat, human and community development, timber, recreation, protection, and multiresource evaluation.

RESEARCH LOCATIONS

Research Work Units of the Rocky Mountain Station are operated in cooperation with universities in the following cities:

Albuquerque, New Mexico
Flagstaff, Arizona
Fort Collins, Colorado *
Laramie, Wyoming
Lincoln, Nebraska
Rapid City, South Dakota
Tempe, Arizona

*Station Headquarters: 240 W. Prospect St., Fort Collins, CO 80526